CLAIMS

1. A method for mitigating radio frequency (RF) interference in a multicarrier modulation system, said method comprising the operations of:

(a) obtaining frequency domain data associated with a frequency band;

(b) identifying a restricted frequency sub-band within the frequency band;

(c) estimating a frequency of the RF interference within the restricted frequency sub-band;

(d) estimating the RF interference in accordance with a frequency domain model for the RF interference and the estimated frequency of the RF interference; and

(e) removing the estimated RF interference from the frequency domain data.

2. A method as recited in claim 1, wherein the frequency domain data is provided in a plurality of frequency tones within the frequency band, and

wherein the frequency domain model is produced in accordance with the following equation:

$$RFI_{n+m} = \left[\sum_{k=1}^{MO+1} \frac{A_k}{(m-\delta)^k} \right]$$

where RFI_{n+m} is the RF interference at a frequency tone n+m due to a radio interferer at frequency (n+δ), δ is an offset amount, MO is a model order for the frequency domain model, and A_k is a complex number that is determined for each frequency tone m.

3. A method as recited in claim 1, wherein the RF interference is due to radio transmissions by an amateur radio operator.

4. A method as recited in claim 1, wherein the frequency restricted sub-band is approximately one of: 1.8 to 2.0 MHz; 3.5 to 4.0 MHz; 7.0 to 7.3 MHz and 10.1 to 10.15 MHz.

5. A method as recited in claim 1, wherein the frequency domain data contains a plurality of frequency domain data samples, and

wherein said estimating of the frequency of the RF interference comprises the operations of:

determining a largest data sample of the frequency domain data samples within the restricted frequency sub-band, and determining a largest adjacent data sample that is adjacent to the largest data sample; and

determining the frequency of the RF interference within the restricted frequency sub-band based on the largest data sample and the largest adjacent data sample.

6. A method as recited in claim 1, wherein the frequency domain model is based on a time domain model for the RF interference in which the RF interference is modeled as a windowed, modulated sinusoid.

7. A method as recited in claim 6, wherein the sinusoid is modulated by a windowed, modulation envelope.

8. A method as recited in claim 6, wherein the sinusoid is modulated by a linearly-varying, windowed, modulation envelope.

9. A method as recited in claim 6, wherein the sinusoid is modulated by a n^{th} order polynomial modulation envelope.

10. A method as recited in claim 1, wherein the frequency domain data contains a plurality of frequency domain data samples,

wherein said estimating the RF interference estimates the RF interference for at least a portion of the frequency domain data samples, and

wherein said removing of the estimated RF interference from the frequency domain data comprises, for each of the frequency domain data samples in the portion, the operation of subtracting from the frequency domain data sample the estimated RF interference on that frequency domain data sample.

11. A method as recited in claim 10, wherein the frequency domain data contains a plurality of frequency domain data samples, and

wherein said estimating of the frequency of the RF interference comprises the operations of:

determining a largest data sample of the frequency domain data samples within the restricted frequency sub-band, and determining a largest adjacent data sample that is adjacent to the largest data sample; and

determining the frequency of the RF interference within the restricted frequency sub-band based on the largest data sample and the largest adjacent data sample.

12. A method as recited in claim 11, wherein the frequency domain model is based on a time domain model for the RF interference in which the RF interference is modeled as a modulated sinusoid.

13. A method as recited in claim 12, wherein the RF interference is due to radio transmissions by an amateur radio operator.

14. A method as recited in claim 13, wherein the frequency domain data is provided in a plurality of frequency tones within the frequency band, and

wherein the frequency domain model is produced in accordance with the following equation:

$$RFI_{n+m} = \left[\frac{A}{m-\delta} + \frac{B}{(m-\delta)^2}\right] W_m.$$

where RFI_{n+m} is the RF interference at a frequency tone n+m due to a radio interferer at frequency (n+δ), δ is an offset amount, W_m is an attenuation factor due to time domain windowing and varies with each of the frequency tones, and A and B are complex numbers.

15. A method as recited in claim 14, wherein A and B are model parameters and are determined by the following equation:

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} -1 & 1 \\ 1-\delta & \delta \end{bmatrix} \begin{bmatrix} \delta^2 \dfrac{X_n}{W_0} \\ (1-\delta)^2 \dfrac{X_{n+1}}{W_1} \end{bmatrix}$$

where the complex parameters A and B are determined once for each symbol, and the offset amount δ is computed once per symbol for each RF interferer being modeled.

16. A method as recited in claim 1, wherein the frequency domain data contains a plurality of frequency domain data samples,

wherein said method further comprises the operation of comparing the frequency domain data samples within the restricted frequency band with a threshold amount, and

wherein, for the restricted frequency band, at least one of said estimating (d) and said removing (e) are bypassed when said comparing determines that the frequency domain data samples are less than the threshold amount.

17. A method as recited in claim 1, wherein no data is transmitted in the restricted frequency sub-band.

18. A method as recited in claim 1, wherein said obtaining (a) of the frequency domain data is initially received as time domain data, the time domain data undergoes a time domain windowing operation, and thereafter the windowed time domain data is converted to the frequency domain.

19. A method for mitigating radio frequency interference in a multicarrier modulation system, said comprising the operations of:

prior to data transmission,

identifying AM radio interference in the multicarrier modulation system;

estimating a frequency of the AM radio interference;

disabling certain frequency tones of the multicarrier modulation system adjacent to the estimated frequency of the AM radio interference from carrying frequency domain data during the data transmission;

thereafter, during or following data reception,

estimating the AM radio interference in accordance with a frequency domain model for the AM radio interference and the estimated frequency of the AM radio interference; and

removing the estimated AM radio interference from the frequency domain data.

20. A method as recited in claim 19, wherein said identifying of the AM radio interference is performed during an initialization period of the multicarrier modulation system that occurs prior to data transmission.

21. A method as recited in claim 19, wherein the frequency domain data contains a plurality of frequency domain data samples, and

wherein the frequency domain data is initially received as time domain data, the time domain data undergoes a time domain windowing operation, and thereafter the windowed time domain data is converted to the frequency domain.

22. A method as recited in claim 19, wherein the AM radio interference resides within a AM radio band,

wherein the frequency domain data contains a plurality of frequency domain data samples, and

wherein said estimating of the frequency of the AM radio interference comprises the operations of:

determining a largest data sample of the frequency domain data samples within a frequency range, and determining a largest adjacent data sample that is adjacent to the largest data sample; and

determining the frequency of the AM radio interference within the frequency range based on the largest data sample and the largest adjacent data sample in a portion of the radio band.

23. A method as recited in claim 22, wherein the frequency domain model is based on a time domain model for the RF interference in which the RF interference is modeled as a windowed, modulated sinusoid.

24. A method as recited in claim 23, wherein the sinusoid is modulated by a windowed, modulation envelope.

25. A method as recited in claim 23, wherein the modulated is modulated by a linearly-varying, windowed, modulation envelope.

26. A method as recited in claim 23, wherein the sinusoid is modulated by an n^{th} order polynomial modulation envelope.

27. A method as recited in claim 19, wherein the frequency domain data contains a plurality of frequency domain data samples,

wherein said estimating the AM radio interference estimates the AM radio interference for at least a portion of the frequency domain data samples, and

wherein said removing of the estimated AM radio interference from the frequency domain data comprises, for each of the frequency domain data samples in the portion, the operation of subtracting from the frequency domain data sample the estimated AM radio interference on that frequency domain data sample.

28. A method as recited in claim 27, wherein the AM radio interference resides within a AM radio band,

wherein the frequency domain data contains a plurality of frequency domain data samples, and

wherein said estimating of the frequency of the AM radio interference comprises the operations of:

determining first and second largest data samples of the frequency domain data samples within the portion of the frequency domain data samples; and

determining the frequency of the AM radio interference based on the first and second largest data samples in a portion of the radio band.

29. A method as recited in claim 28, wherein the frequency domain model is based on a time domain model for the AM radio interference in which the AM radio interference is modeled as a modulated sinusoid.

30. A method as recited in claim 29, wherein the AM radio interference is due to radio broadcasts by radio stations.

31. A method as recited in claim 30, wherein the frequency domain data is provided in a plurality of frequency tones, and

wherein the frequency domain model is produced in accordance with the following equation:

$$RFI_{n+m} = \left[\frac{A}{m-\delta} + \frac{B}{(m-\delta)^2} \right] W_m.$$

where RFI_{n+m} is the RF interference at a frequency tone n+m due to a radio interferer at frequency $(n+\delta)$, δ is an offset amount, W_m is an attenuation factor due to time domain windowing and varies with each of the frequency tones, and A and B are complex numbers.

32. A method as recited in claim 31, wherein A and B are model parameters and are determined by the following equation:

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} -1 & 1 \\ 1-\delta & \delta \end{bmatrix} \begin{bmatrix} \delta^2 \dfrac{X_n}{W_0} \\ (1-\delta)^2 \dfrac{X_{n+1}}{W_1} \end{bmatrix}$$

where the complex parameters A and B are determined once for each symbol, and the offset amount δ is computed ~~once per symbol for~~ each RF interferer being modeled.

33. A method as recited in claim 19, wherein the frequency domain data contains a plurality of frequency domain data samples,

wherein said method further comprises the operation of comparing the frequency domain data samples with a threshold amount, and

wherein at least one of said estimating the AM radio interference and said removing of the estimated AM radio interference are bypassed when said comparing determines that the frequency domain data samples are less than the threshold amount.

34. A method as recited in claim 19, wherein said estimating of the AM radio interference further being in accordance with the frequency domain data on the certain frequency tones on which no data, just AM radio interference, is present.

35. A method as recited in claim 19, wherein said estimating of the frequency of the AM radio interference is performed while data is not being transmitted.

36. A method as recited in claim 19, wherein the frequency domain data is provided in a plurality of frequency tones, and

wherein the frequency domain model is produced in accordance with the following equation:

$$RFI_{n+m} = \left[\sum_{k=1}^{MO+1} \frac{A_k}{(m-\delta)^k} \right]$$

where RFI_{n+m} is the RF interference at a frequency tone n+m due to a radio interferer at frequency (n+δ), δ is an offset amount, MO is a model order for the frequency domain model, and A_k is a complex number.

37. A method for digitally filtering multicarrier modulation samples to reduce sidelobe interference from a radio frequency (RF) interferer, the multicarrier modulation samples occur at predetermined frequency tones and form a multicarrier modulation symbol, said method comprising the operations of:

receiving x samples of a multicarrier modulation symbol and y samples of a cyclic prefix associated with the multicarrier modulation symbol, the y samples of the cyclic prefix preceding the x samples of the multicarrier modulation symbol;

discarding an initial portion of the y samples of the cyclic prefix associated with the multicarrier modulation symbol;

storing a remaining portion of the y samples of the cyclic prefix associated with the multicarrier modulation symbol;

retaining a first portion of the x samples of the multicarrier modulation symbol without modification; and

modifying a second portion of the x samples of the multicarrier modulation symbol in accordance with the stored samples of the remaining portion of the y samples of the cyclic prefix and predetermined multiplication coefficients.

38. A method as recited in claim 37, wherein said receiving of the x samples of a multicarrier modulation symbol and y samples of a cyclic prefix associated with the multicarrier modulation symbol is a stream of data received over a transmission media from a transmitter of a multicarrier modulation system.

39. A method as recited in claim 38, wherein the transmission media is a subscriber line.

40. A method as recited in claim 37, wherein for each x samples of the multicarrier modulation symbol, said method uses j multiply operations and 2j addition operations for performing said modifying, where j is an integer representing the number of samples in the remaining portion of the y samples of the cyclic prefix.

41. A method as recited in claims 40, wherein the predetermined multiplication coefficients are associated with a raised cosine function.

42. A method as recited in claim 37, wherein said modifying of the second portion of the x samples of the multicarrier modulation symbol comprises:

retrieving an appropriate one of the predetermined multiplication coefficients;

determining a difference amount between corresponding pair of samples of the remaining portion of the y samples of the cyclic prefix and the second portion of the x samples of the multicarrier modulation system;

multiplying the difference amount with the appropriate one of the predetermined multiplication coefficients to produce an adjustment amount; and

adding the adjustment amount to the sample of the second portion of the x samples of the corresponding pair.

43. A method for digitally filtering DMT samples to reduce sidelobe interference from a radio frequency (RF) interferer to frequency tones of a DMT symbol, said method comprising:

receiving X samples of a DMT symbol and Y samples of a cyclic prefix associated with the DMT symbol;

discarding an initial portion of the Y samples of the cyclic prefix;

storing a remaining portion of the Y samples of the cyclic prefix;

retaining a first portion of the X samples of the DMT symbol without modification; and

modifying a second portion of the X samples of the DMT symbol in accordance with the stored samples of the remaining portion of the Y samples of the cyclic prefix and predetermined multiplication coefficients.

44. A method as recited in claim 43, wherein said modifying operates to attenuate sidelobe interference from a radio frequency (RF) interferer at a rate faster than would occur without said modifying.

45. A method as recited in claim 43, wherein said method reduces the number of the frequency tones of the DMT symbol that are closest to the frequency of the RF interferer than are seriously impacted by the RF interference.

46. A receiver for a multicarrier modulation system, comprising:

an analog-to-digital (A/D) converter , said A/D converter receives analog signals that have been transmitted to said receiver over a transmission media and converts the analog signals to digital time domain signals;

a multicarrier demodulator operatively connected to said A/D converter, said multicarrier modulator receives the digital time domain signals and converts the digital time domain signals into digital frequency domain data; and

a digital RF interference canceller operatively coupled to said multicarrier demodulator, said digital RF interference canceller mitigates the effect of RF interference on the digital frequency domain data by modeling the RF interference in accordance with a frequency domain model.

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47. A receiver as recited in claim 46, wherein said digital RF interference canceller mitigates the effect of RF interference on the digital frequency domain data by estimating a frequency of the RF interference, estimating the RF interference in accordance with the frequency domain model for the RF interference and the estimated frequency of the RF interference, and removing the estimated RF interference from the digital frequency domain data.

48. A receiver as recited in claim 46, wherein the digital frequency domain data is provided on a plurality of frequency tones used by the multicarrier modulation system, and

wherein the frequency domain model is produced in accordance with the following equation:

$$RFI_{n+m} = \left[\sum_{k=1}^{MO+1} \frac{A_k}{(m-\delta)^k} \right]$$

where RFI_{n+m} is the RF interference at a frequency tone n+m due to a radio interferer at frequency (n+δ), δ is an offset amount, MO is a model order for the frequency domain model, and A_k is a complex number.

49. A receiver as recited in claim 46, wherein the digital time domain signals include a plurality of multicarrier modulation symbols carrying data, each of the symbols having a cyclic prefix,

wherein said receiver further comprises:

a cyclic prefix removal and windowing processor operatively connected between said A/D converter and said multicarrier demodulator, said processor performs a time domain windowing operation on the symbols, the time domain windowing